# Position paper

## NIH/NSF Workshop on Visualization Research Challenges

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I believe that the visualization field is stagnating. Instead of addressing new fundamental challenges that allow scientists and engineers to explore massive time-varying multi-valued data sets, we are pushing incremental updates to prior solutions. Our field is largely driven by improvements in technology, and not by new visualization solutions that are necessary to makes fundamental advances in discovery and analysis of complex data. I believe that we need to think "outside the visualization box," identifying new "visualization" research challenges, not continue to provide incremental updates to existing solutions. I can identify 11 areas in which "thinking outside the box" may have a significant impact on the results of our field.

1. Think outside the "scalar field." In the 2003 Dagstuhl seminar on Visualization there were over 30 talks concerning scalar fields. Yet there are fundamental scientific and engineering problems concerning vector fields, tensor fields, multi-valued fields, segmented fields, and fields that have distributions (or functions) at each data point. We must find ways to allow our users to explore these data types.

2. Think outside "2-D." Three-dimensional time-varying multi-valued data exploration is HARD. However, the data calculated through computational simulations, or returned by data collection devices, are precisely of this form. What are the topological properties of three-dimensional vector fields, or three-dimensional tensor fields, or three-dimensional distribution fields that give the user fundamental information about the field?

3. Think outside the "big three" algorithms of visualization. Are there other fundamental visualization algorithms besides slicing, creating isosurfaces, and volume rendering?

4. Think outside the "pretty picture." I believe there is little correlation between the beauty of a visualization in the information in supplies to the user. I believe we need to sever our roots with the pretty-picture community and address the fundamental problems of data exploration, presenting useful information to the user that allows insight into the data.

5. Think outside the "GPU." Programming the GPU is research in programming, not research in visualization. The computer graphics field has been driven for last 30 years by the advances in computer graphics hardware. I do not believe that advances in visualization should be based

on the advances in computer graphics hardware.

6. Think outside the "static data set." The problems of the world are not static problems! We need to develop solid solutions to allow the user to explore time-varying multi-valued data.

7. Think outside the "heuristic." The field of visualization should be based on fundamental mathematical principles. We need to work in the world of theorems. Theorems require deeper thinking about the subject and can show was ways to get out of our "box." Corollary: Think outside of "linear."

8. Think outside the "multiresolution" box. Subdivision, wavelets, splines, and mesh simplification have broad mathematical roots, I believe the key to massive data visualization is simply deciding what to visualize. The key is to focus on the data exploration task, and not show absolutely everything (or simplify absolutely everything). We need to make queries -- visualization queries -- on our data sets. We need to find regions of interest to the user and let the user explore these regions.

9. Think outside the "mesh". Our field has developed incremental algorithms that extend the basic algorithms of visualization (e.g., marching cubes) from regular meshes, to unstructured meshes, to AMR meshes, to multiblock meshes, to zoo meshes, etc. Meshless techniques can solve all these problems under one umbrella, and the mathematics of scattered data interpolants is well researched and understood.

10. Think outside the terms "scientific visualization" and "information visualization." Many researchers consider these separate fields. I believe we should look to find a common links between these fields and exploit them.

11. Think outside the "academic problems." Are we solving problems to allow scientists and engineers to explore data and discover useful information about their data, or are we solving incremental academic problems? If our field were solving the fundamental data exploration problems that have a maximum impact on analysis and discovery, then scientists, engineers, and users of visualization tools would be attending our conferences. They are not!

I believe that it is time for the researchers in our field to address the more fundamental problems in data exploration that will influence analysis and discovery of the basic knowledge contained in complex data sets.